

HANDLING OF HAZARDOUS MATERIALS
IN OIL AND GAS FIELD DEVELOPMENT
IN ALBERTA

EVIDENCE OF

MR. D. R. SHAW

EXHIBIT NO. 440-1 Jan 28/76
Invent. W.T.
C.O.P.E.

C.O.P.E. DELTA PHASE
BERGER INQUIRY
JANUARY 1976

CONTENTS

Evidence 1

Appendix I Reports referred to or relied on 26

Appendix II Biographic information, D. R. Shaw 27

Q. 1. Would you list the oil and gas field problems that you are most commonly involved with during the course of your work in Alberta?

A. In general, my work relates to various aspects of the impact of the oil industry upon the environment, with particular interest in industry's practice of:

- (a) oil spill clean-up, prevention, and restoration;
- (b) salt water spill clean-up, prevention, and restoration;
- (c) sump fluid disposal;
- (d) general housekeeping - on and off lease; and
- (e) oil spill contingency preparedness.

I also have occasion to become directly or indirectly involved in various research aspects of rehabilitative schemes where hazardous materials have been spilled. This includes investigations of subjects such as:

- (a) the extent to which fertilizers can aid rehabilitation;
- (b) the best method of overcoming oil spills on arable land;
- (c) how best to handle oil spills on muskeg areas;
- (d) how to aid recovery after a salt spill;
- (e) the proper use of chemicals as a distinct aid to site clean-up in relation to oil spills;
- (f) the development of oil spill containment techniques as applicable to lakes and streams in winter and summer;
- (g) line break detection in summer and winter;
- (h) the restoration of spill sites; and
- (i) the possibility that bacteria inside or outside of pipelines are capable of greatly increasing the rate of corrosions and hence generating line failures.

Work in these subjects has required me to become deeply involved in evaluation of the toxicity of various wastes, effluents, and spills, as well as the toxicity of chemicals and detergents in normal usage.

Q. 2. You used the word "toxicity". Will you explain what you mean when you use this word?

A. The term "toxicity" or "toxic" does not necessarily imply death of an organism, but does signify that a plant or animal was disadvantaged. Sometimes this disadvantage may be great enough to cause death of the organism. In the testing that I have done it has been the usual practice to test various concentrations of materials in water by aerating and cooling the solution and then adding rainbow trout (*Salmo gairdneri*, Richardson). Care is exercised to ensure that no "ocean-run" strains of trout are used for test purposes.

I should also add that materials at concentrations that do not kill fish within a certain time limit can *NOT* be considered as non-toxic only as relatively less toxic than substances which kill more readily.

Q. 3. If we consider oil and gas field development generally, without reference to any particular field, what kinds of fluids are brought to the surface during production?

A. Formation fluids consist of mixtures of hydrocarbons and salt water, and may also contain various amounts of sulphur compounds such as hydrogen sulphide and mercaptans. These components may be present in almost all conceivable proportions - some formation fluids contain no water, some are all water, some consist of only light hydrocarbons ie. are natural gas, some only very heavy hydrocarbons, and finally these fluids may be sour (containing sulphur compounds) or contain no sulphur compounds and are referred to as being sweet. This is largely dependent upon the formation of origin.

Q. 4. What is the significance of this variability and complexity of formation fluids when it comes to spills and their treatment?

A. Unfortunately a spill of formation fluid will often consist of more than a crude oil spill problem. Each of the major components of the fluid can generate its own set of unique problems. The causes of these problems often obscure each other to the extent that what appears to be a simple oil spill may not respond to treatment. Examination and analysis may show for example that the oil spill also contained a salt spill. The salt could have been present in the crude oil as free brine, or as emulsified salt water, or as suspended micro-crystals in the oil. A high concentration of salt in the oil could have a serious effect on the rehabilitation programme. Crude oils have been tested which contained 20,000 lbs. of salt per 1000 barrels of crude oil.

A crude oil spill may therefore consist of three intertwined problems:

- A. A hydrocarbon problem.
- B. A mercaptan and hydrogen sulphide problem.
- C. A salt problem.

Q. 5. Would you describe the hydrocarbon problem in more detail?

A. The hydrocarbons in crude oil are present in a variety of forms; some are volatile, some are waxy solids, and some are tarry solids, depending upon the kind of crude oil that is involved. Crude oils may be categorized as several types:

- 1) paraffinic;
- 2) naphthenic;
- 3) aromatic;
- 4) asphaltic.

Each of these types of crude oils has a light (gasoline like) fraction and several heavy (oily, tarry, or waxy) fractions. Each fraction has a different solubility in water, and *usually* this appears to modify the overall undesirable effects on various species of



Digitized by the Internet Archive
in 2025 with funding from
University of Toronto

<https://archive.org/details/31761120644109>

animals and plants encountering the crude oil.

I would not presume that all water soluble hydrocarbons are toxic and conversely that all water insoluble hydrocarbons are non-toxic. Generally speaking, condensates, light hydrocarbons, l.p.g.'s, light gasolines, etc., are much more toxic than the heavy straight run diesel fuels, lube oils, etc. quite probably due to the high proportion of low molecular weight very soluble material present in the lighter fractions. In practice you must be careful; eg. one product, a straight run winter diesel fuel, from a paraffin base crude, is toxic only at relatively high levels of concentration (in the 300 mg/litre class). Conversely a summer diesel from the same paraffin base crude has a higher concentration of unsaturated hydrocarbons because it is a blend of straight run distillate plus a cracker stock and possibly even a reformer run. The different blend stock each have different toxicities, depending on the conditions of the run, the input material, and the proportions of each in the final blend. The components of diesel fuel also differ in toxicity to animals depending on the seasons of the year, the sex and development of the animals affected and even the amount of natural oil present.

The toxicity of hydrocarbons is closely allied to the hydrocarbon structure. We all know that a refined wax floating on water will not immediately adversely affect the fish in the water, whereas a gasoline layer on the water will probably adversely affect the fish. It is also evident that the toxicity of hydrocarbons can be related to factors other than their direct solubility in water. For example, animals that are oil wettable such as most insects and many insect larvae seem to die very quickly in oils. Oil is easily absorbed, either through the intact cuticle or via the spiracles, or is ingested by the animal grooming itself (by licking itself) or is eaten with its food. In some cases animals may think that the oil is food. In the case of the animal eating the oil, the gut of the animal may partially or wholly metabolize the oil, or may detoxify it by various mechanisms. Mammals like the domestic cow can *drink* large quantities

of crude oil and survive *provided that all* of the oil enters the stomach. The animal will however, suffer for a time from diarrhoea.

It seems evident that animals which are invariably water wet, such as fish, will not suffer by being coated with oil, mostly because they cannot be coated. However, the soluble hydrocarbons can be absorbed, probably (most easily) via the respiratory system. The secondary toxic effect on fish is due to swallowing oily particles, either composed of oil or of oiled insects or plant food. The effect of this ingested oil does not appear to me to be evident as quickly as the previously mentioned direct absorption of dissolved material. There is of course a tertiary effect which can cause great discomfort and even death to fish and aquatic insect larvae, and that is the reduction of available oxygen. If an oily layer covers a pond, oxygen is prevented from redissolving in the water, therefore a state of oxygen shortage may develop. Less complex organisms (particularly algae) that normally would produce oxygen, then die (either due to toxic effects or blockage of sunlight by the oil layer), hence they do not produce replenishment oxygen.

The dead algae then decay and thus create a high biological oxygen demand, therefore creating an even greater oxygen shortage. The new environment so created may be effectively anaerobic and therefore it is believed that mobile species (such as fish) will move from the contaminated area.

Animals that inadvertently eat the oil try to detoxify the oil by various mechanisms. The type of detoxification attempted by the animals depends on the nature of the substance, the manner of entry to its system, and in some cases the amount entering. There are probably many more governing factors such as age or sex of the animal, time of year, and the fat content of the animal. However the animal system usually makes some attempt to detoxify the material by adding another chemical such as a sugar to it, and by excreting it (changed

or unchanged). Sometimes the animal system destroys itself by mistaking one chemical for another and building an enzyme blocking chemical in an effort at detoxification or by building a carcinogen instead of an excretable material. In the case of the cow, the crude oil that is swallowed appears to go into the "stomachs". There it interferes with normal bacterial activity associated with digestion and is rapidly passed on to the intestines. There it seems to act as an aperient. However, sometimes the cow dies very quickly due to relatively small amounts of oil. It has been shown by Dr. Beck, (1) that an animal that *breathes in* as little as a half a cup of crude oil will probably very soon die of some form of pneumonia.

For animals that do become oil wet, such as muskrats, beaver, ducks, geese, and other water birds it is important to understand why a coating of oil on fur or feathers will be a cause of death. Unfortunately, when fur or feathers are matted together with oil, the elements can make an impression on the bare skin of the animal. Oil can be absorbed through the skin, but by far the larger effect generally is the one of exposure, since the skin of an oiled animal makes direct contact with the elements without intervening insulation.

Q. 6. Is there anything that can be done to counteract some of these undesirable environmental aspects of the hydrocarbon problem?

A. Volatile hydrocarbons can be removed from the water by passing a current of clean air through the contaminated water. A large proportion of the volatile hydrocarbon will be swept out with the effluent air.

Oiled animals should be washed free of oil, dried, fed, and when back to normal, released in an area free of oil. The animal if properly treated will very often survive. Oiled animals react to oil by increasing their metabolic rate in order to keep themselves warm and possibly in a defence mechanism similar to the one which produces a "fever" in man when he has an infection. The increase in the

heat output uses up stored fat, and eventually muscle tissue, and unless the animal is fat and well favoured, and not "frightened to death", it will soon perish.

The action of washing an animal so that it becomes free of oil has certain hazards associated with it. One must:

- 1) ensure that the mammal or bird, tranquillized or not; does not breathe in the oil or the oily soapy water;
- 2) be very careful to rinse away all the oily soapy water from the fur, feathers, and skin;
- 3) exercise care in disposal of the oily soapy water since a mixture of oil and detergents in water is usually much more toxic than either the oil in water or the detergent in water by themselves. Generally speaking the cumulative effect is synergistic rather than additive. Disposal of oily soapy water should be to a dry land surface which is supporting a grass or other crop. Detoxification by soil bacteria, sunlight and air will generally proceed fairly rapidly in such a "safe" place;
- 4) handle wild animals very cautiously because they cannot understand or appreciate our actions, and generally must interpret handling as some form of aggression. They therefore retaliate and react against the rescuer as if he were a predator. The result can be damaging to the rescuer, but of greater importance is the probability that the animal may die of shock and mis-handling. Be gentle, or your concern and effort will go unrewarded insofar as saving the life of an affected animal.

Another solution to pollution is to generate and use only those materials which have a minimal effect on the environment. This activity might even best be performed by the manufacturers. They can often remove dangerous trace components or by-products if the customer requires that this be done prior to purchase.

Q. 7. Earlier you referred to the mercaptan and hydrogen sulphide problem. Can you explain why these chemicals are of concern?

A. Generally speaking, the content of hydrogen sulphide (H_2S) and mercaptan (RSH) is kept as low as possible in most materials shipped by pipelines because these materials are corrosive. The exception is of course that transmitted gas for domestic heating is odorized for safety. Fortunately, RSH and similar compounds are very easily detected by us, therefore the level of RSH in commercial gas is kept low (circa 10 ppm). However, the raw product streams from well heads and flow lines etc, may contain H_2S and RSH and these compounds are very toxic.

The Worker's Compensation Board of Alberta classes hydrogen sulphide gas as "one of the most vicious and deadly hazards in Alberta!"(2). A hydrogen sulphide victim may suffer little or no lasting ill effects if moved into fresh air and given artificial respiration. The odor is a warning; its disagreeable nature (the smell of rotten eggs) warns animals of its presence. If, in spite of the warning, the animal chooses to disregard the offensive odor, then the animal will lose its sensitivity to the odor of hydrogen sulphide. The animal may then totally disregard the originally noticed warning odor, remain in the area of high concentration and if the hydrogen sulphide concentration is great enough the animal will die. Man, although not as sensitive to odors as other animals, is still subject to loss of odor sensitivity as are other animals, and consequently to a similar loss of life.

Hydrogen sulphide and the chemically similar mercaptans (RSH) are poisonous to most fish and most invertebrates at levels of 1 ppm H_2S in water or less. Unfortunately, the low molecular weight mercaptans and hydrogen sulphide are quite soluble in water (up to 6649 ppm of H_2S is soluble in water @ 0 degrees C) (3), and hence is very effective as a poison. Condensates containing hydrogen sulphide and mercaptans (RSH), when spilled on or into water, make contact with the water and the

hydrogen sulphide and mercaptans (RSH) dissolve very rapidly into the water. The resultant water can then be very toxic to aquatic life even after total removal of the hydrocarbon from the surface.

Q. 8. What can be done to counteract these problems with hydrogen sulphide and mercaptans?

A. The only method of removal of some of the sulphur compounds is by air stripping. This will also remove much of the dissolved hydrocarbons. Therefore if a perforated compressed air line is put into the water, some of the poisonous sulphur compounds and the soluble hydrocarbons will strip out with the air.

Q. 9. Would you describe the salt problem in more detail?

A. Salt is always present in formation fluids, and may be the major portion of the fluid if brine only is produced, or it may be present in crude oils and condensates in what can be considered to be two forms: as a crystalline or micro-crystalline solid suspended in the oil, or as water solution. On contact with the water in the environment (whether that water is interstitial water in soil, surface water of a stream, slough or lake, or precipitation as rain or snow) the salt will appear in the fresh water and contaminate that water. The salty water must then be considered in much the same way as a salty formation fluid spill must be considered.

Salt water may come from several sources:

- a) from spilled crude oil or other hydrocarbons;
- b) from production tank bottom sludge, called B.S. & W.;
- c) from reproduced water or sludge;
- d) from disposal or injection line breakage;
- e) from sump fluids accumulated during well drilling.

Whatever the source, it is critical to know how concentrated the salty material is, since the method of rehabilitation is adjusted according to the volume and salinity of the water involved.

The biological effect will also depend on the volume and salinity of the water solution; therefore, it is important to know how much is being dealt with and of what concentration. The following examples will illustrate.

- 1) a small oil spill into a small slough has occurred: -
the salt content of the oil is found to be 100 lbs/1000 bbls.; the spill is only 100 bbls.; the slough is 300 ft. long by 100 ft. wide and 4 ft. deep in the centre. Then the volume = $\frac{300 \times 100 \times 4 \times 6.25}{2} = 375,000$ gallons. The amount of salt in 100 barrels of crude oil is $\frac{1}{10}$ of 100 lbs. = 10 lbs. of salt. Therefore the crude oil spill of 100 barrels of crude oil into the slough may put 10 pounds of salt into solution in the 375,000 imperial gallons of slough water. This amounts to about 3 ppm of salt and will pose no problem.
- 2) a large oil spill into the same slough: consists of 10,000 barrels of oil containing 1500 lbs./salt per 1000 barrels. In this case there is 15,000 lbs. of salt dissolved in 375,000 imperial gallons of slough water. This amounts to 15,000 lbs. of salt in 3,750,000 lbs. of water. The resultant concentration is then about 4000 ppm of salt and will be a problem to many plants and animals.

With these points in mind we must also realize that the salty water can affect everything that comes in contact with it. Mammals may drink it; fish of course can not escape, and neither can the fish food organisms. If the salty water goes on the land, we must appreciate the fact that the animals in the soil will also be affected, as of course may be the plants.

Q. 10. What are some of the effects of salt on animal and plant life?

A. Much work has been done in Southern California and Australia on the salt problem in relation to livestock. Sheep can stand the highest concentration of salt in the drinking water, about 10,000 ppm of dissolved salts. Next would come cattle and horses at about 8,000 ppm, then pigs at about 6,000 ppm. These levels eventually induce a weight loss and interfere with food assimilation and weight gain and eventually the animal would lose weight and vigor to the point of emaciation and probably death.

Ducks appear to be able to stand about 5,000 ppm, while turkeys and chickens as adults can tolerate about 3,000 ppm. Turkey poults begin to die at 1800 ppm.

Fish can sometimes tolerate considerable quantities of salt, not simply if they are ocean fish, but fresh water fish. Some, (like the rainbow trout as adults) can stand concentrations approaching 20,000 ppm. However, they must be a year old and acclimatized to this concentration. If you test salt solutions in conductivity water using fingerling trout you will find that many monovalent salts above 20 ppm will soon kill them. Further checking will reveal that this will not occur if you have a considerable concentration of calcium or magnesium ion present. The result is that one can sometimes approach 9,000 ppm of monovalent salt provided that there is a high calcium content (approaching 3,000 ppm) without killing the fish. Unfortunately other factors often interfere such as dissolved oil, mercaptan, and detergent; and the calcium ion does not appear able to help to overcome the effect of these organic poisons. Salt tends to cause another problem and that is the dispersion of fine particles. These fine particles can be lethal to invertebrates.

I have found aquatic invertebrates to be very sensitive, so much so that I hesitate to use them as a test species to determine toxicity. Generally speaking the food organisms of the fish, (commonly the

larvae forms of the aquatic insects) seem to be more sensitive to pollutants than are the fish. Nature has worked this out very neatly; if the fish food dies quickly, then there is little food for the fish, the fish will then search elsewhere for food and will then swim out of the high concentration of pollutant. There are of course many exceptions to this idea; some insects tolerate tremendous concentrations of deleterious materials, and some fish are attracted to lethal zones of high concentrations of certain pollutants.

Invertebrates in soil are also generally destroyed by salt concentrations similar to those mentioned above. The dispersed clay becomes both an air and water block and animals in the soil may suffocate when trapped in or under the solodized layer. Buried salt can migrate to the surface from pits or buried sites; brines which disappear have not necessarily evaporated and ceased to be a problem.

Plants die by what appears to be the direct action of salt. Some species of wheat and rye grasses can stand quite high concentrations. Experimental watering of trees showed that pine trees died when water containing 500 ppm of chloride (as sodium chloride) was used as their only water source, whereas white spruce managed to live when irrigated with 1,500 ppm of chloride (as sodium chloride). One of the wheat grasses appeared to tolerate 4,000 ppm chloride. Some weed seeds will germinate even at 25,000 ppm chloride. Plants seem to be adversely affected by salt in several ways: one is directly due to salt interfering with osmotic transport causing destruction of various cells; and another is indirect and is linked to the buildup of toxic materials below the solodized layer. In the anaerobic conditions below this layer there is a tendency for sulphate reducing bacteria (*Desulphovibrio desulphuricans*) to thrive. These produce hydrogen sulphide, which is lethal to plants as well as to most animals as already noted.

Q. 11. Would you outline the problems that arise in connection with disposal of sump fluids?

A. The process of drilling an oil or gas well customarily generates a considerable volume of waste water (three or four million gallons could be generated by a single deep well). This water, if liberated incautiously, can have an adverse impact upon the environment.

A sump is a catch-all for holding waste products, slop water, or temporarily storing material prior to transfer to another point. Usually little attention is paid to its contents. In the oil well drilling industry, the drilling fluid, the rig wash water, and often much of the surface run-off water in the area of the rig, all drain into a hole bulldozed into the lease area, and frequently banked with the fill dirt. This constitutes the sump. The wash water may assume a large volume due to the need of cleaning the drilling floor after various operations have spilled mud on the floor.

Because the sump is usually contaminated with drilling fluids, we should first consider why drilling fluids are needed, what they are made of, and what their properties are.

A drilling fluid is needed to lubricate and cool the bit, and also to return the cut rock to the surface. At the surface, the cuttings are screened away from the drilling fluid and the fluid is returned to its own pit. This pit acts as a sump reservoir for the mud pump to recirculate the fluid for more cuttings returns. The muddy cuttings usually find their way into the sump as another waste product, after small sacks of them are collected for the geologist at various footages drilled. Water alone (or even air) could be used to cool the bit and return the cuttings; the only apparent problem would seem to be the obvious one of velocity. Therefore, it would appear that if you used a big enough pump you could clean any debris (cuttings or even iron) out of the hole. This (like most sweeping statements) is a half truth, and leaves you sometimes

high temperature and pressure peculiarities, since some holes will be 18,000 feet deep and may take over a year to drill. The final sump then contains surface slops, rig-wash detergents, spilled diesel fuel, brine from packer tests of formations, sometimes crude oil, special dispersants, precipitants, acid from acid washes, frac fluid, emulsifying agents, humic acids, tannic acids, ligno-sulphonates, chemicals for drilling mineral beds, cement slurries, etc. The contents of the sump reflect the history of the entire drilling operation - from spudding to eventual production or abandonment. The volume of fluids in the sump is exponentially related to the depth of hole drilled, the problems encountered and the length of time it has taken to drill the hole. This volume may be in excess of 100,000 barrels. Fortunately, this is a rare occurrence, but concerned regulatory bodies should keep this in mind.

Experimental work done at the Energy Resources Conservation Board Laboratory indicates that many of the chemicals used in drilling fluids are toxic to plant and animal life. Some are synergistic with other commonly used or frequently spilled compounds. Synergism is the ability possessed by certain pairs of compounds such that they mutually cooperate to produce an effect greater than the sum of the effects produced by each component alone. A few of the materials used in drilling fluids are either not toxic, or are only toxic in very high and seldom used concentrations. A very few inorganic salts appear to be anti-synergistic.

Q. 12. What is the nature of the materials used during the drilling process and can their interactions be determined?

A. The determination of all of the synergistic and anti-synergistic effects of the millions of possible combinations that could be produced by mixing some of the more than 600 additives would be interesting but virtually impossible to produce. A number of the more important components and combinations of components have been

tested in water using rainbow trout. Based on these tests the following generalizations seem to be justified:

- (a) some hydrocarbons such as crude oil produced from formation tests may not be lethal until the concentration is over 400 mg/l;
- (b) some detergents such as rig-wash compounds are not lethal until the concentration is over 200 mg/l;
- (c) many of the oil and detergent combinations that separately are lethal at fairly high concentrations are extremely lethal as mixtures when quite diluted;
- (d) stable suspensions of colloidal material (like the bentonite of the drilling mud) are lethal to fish, because they coat and suffocate. The clear fluid extracted from some bentonite suspensions of 10 lbs/bbl (28,570 mg/l) of bentonite were not lethal to rainbow trout in 96 hours;
- (e) diesel fuel from fuel spills and machine clean-up, depending upon the method of manufacture, may be very toxic;
- (f) the clear water extracted from a diatomaceous earth slurry as used in drilling muds is not toxic even when the slurry used 5 lbs/bbl (14,285 mg/l);
- (g) a particular brand of reagent grade KCl was quite lethal - at concentrations as low as 1 mg/l. This was unexpected since sodium salts are not toxic below 20 mg/l. KCl is used in special drilling muds;
- (h) ammonium phosphate and ammonium sulphate which are used in drilling muds to inhibit clay swelling, are both toxic at the same low concentration. This should be expected since ammonia is dangerous to most animal life at quite low concentrations, (less than 100 mg/l);
- (i) many of the polyacrylamide bentonite flocculants or extenders used in drilling fluids are not toxic at low concentrations (below 100 mg/l). This is well within the effective range;
- (j) corrosion inhibitors from drilling muds or packer tests are generally very toxic (in the same toxicity class as bacteriostats, which they resemble in structure);

- (k) soil sterilants and weed poisons used on the lease are often very toxic to animals, being in the less than 1 mg/l class;
- (l) some humic acid mud thinners are toxic at very low levels of concentration;
- (m) carboxymethylcellulose used in drilling muds as a viscosifier or water loss additive generally is not toxic until beyond the normal usage concentration (possibly because food grades are marketed for use in drilling fluids);
- (n) tanning type mud thinners tend to be less toxic than other thinners (provided that they are tannins and not mixtures containing other materials);
- (o) food grade glycols and some of their polymers which could be used in special muds or as motor, anti-freeze may be only very slightly toxic (20 lbs/bbl or 57,140 mg/l);
- (p) some of the polyethyleneoxy types of detergents or dispersants usable in drilling fluids or as rig wash compounds are only slightly toxic. Some closely related compounds are quite toxic;
- (q) aluminum salts, trivalent metal salts, and alums which may be used to clarify sumps may produce a very toxic solution if the pH is not carefully controlled. The result is that the metal salt which would normally precipitate will remain in solution;
- (r) some lignosulphonate mud thinners are toxic at concentrations exceeding 100 mg/l;
- (s) some of the phosphoric acid ester dispersants, which could be used in drilling fluids or for rig wash compounds, are toxic above the 10 mg/l level;
- (t) rape seed oil which could be used to replace the more poisonous oils in drilling muds is nearly non-toxic (provided that the edible variety - low in erucic acid - is used, and that surface active agents or detergents are absent);
- (u) the clear water extracted from barium sulphate mud weighting material is not toxic;
- (v) powdered gilsonite used in oil emulsion muds is not toxic in concentrations below 0.33 lb/bbl (about 100 mg/l);

- (w) emulsion breakers used in muds seem to be very toxic, in the same class as some corrosion inhibitors and bacteriostats. Some may have similar structures;
- (x) sodium lauryl sulphonate used as a washing compound produces very toxic solutions at low concentrations.

Q. 13. What steps can be taken to alleviate the environmental problems associated with the disposal of drilling sump fluids?

A. If tests have shown that the fluid used at a particular well is toxic, one alternative is to dispose of the fluid to injection wells or disposal wells. Disposal to deep formation presumes that a disposal well is available which satisfies the following conditions:

- (a) it is cased from surface to point of injection;
- (b) it is cased with material that will not corrode;
- (c) that the casing when placed was set in place in such a way that either cement returns were obtained at surface or that every aquifer was squeezed with cement to ensure that even if the casing failed, there could be no contamination of the aquifer;
- (d) that the injection formation be a minimum depth below surface of at least 4000 feet;
- (e) that excessive injection pressures which could rupture the formation or the casing are never employed;
- (f) that the fluid injected be compatible with the natural connate brine such that no insoluble materials are produced when they mix during or subsequent to injection.

However, if the volume for disposal to the lease exceeds 650 bbls/acre (an acre inch) then it can usually not be disposed of to the lease area in one application. In this case, the fluid should be treated with neutralizing agents, absorbents or oxidants which will remove the poisonous chemicals, and which, in themselves, are harmless (or become harmless by the reaction). The effectiveness of the treatment should be confirmed by re-testing the actual field treated sump fluid

with live trout to ensure that it is non toxic; then final disposal can be permitted. The treated fluid may then be disposed of on or off lease, care being taken to not dump the water into water-courses and streams and lakes; or to allow salty but non-poisonous water to inundate sensitive trees. If a sump is in an area which is undulating a very careful choice of area for disposal has to be made. It is important to ensure that:

- (a) no fluids migrate away from the designated area;
- (b) that application rate, weather, etc. are considered;
- (c) relatively bare dry flat areas and meadows are used, as opposed to heavily forested steep slopes and boggy areas;
- (d) no water course or active stream or lake is used as part of the disposal area;
- (e) no valuable timber areas are used as disposal sites;
- (f) gravel and sand pits are not used since fluids which absorb easily tend to migrate elsewhere.

If the water is detoxified and is of such a high volume that continuous disposal to a limited area will only generate a high volume of run-off water, it is necessary to consider devising an irrigation scheme. To do this it is necessary to obtain composite samples of soils from the cleared disposal area. These samples must then be delivered to a competent soils laboratory, together with a large volume of water from the sump in question. The soils specialist will then tell you how much of that kind of water can be spread on that soil, with fertilization or other treatment, provided that a grass or legume crop is properly established first, etc.

If the sump is generated in winter, it has been found possible and economical, through heating and circulating equipment, to detoxify a dangerous sump. Generally, sumps which are lethal should be held for summer-time treatment and disposal. Large volume disposal of sumps in winter-time tends to become part of the spring run-off and could create local toxicity problems.

Furthermore, the addition of irrigation water to frozen ground could cause freezing of the delivery lines and would not deliver the water to be absorbed into the soil where it is least likely to do any harm.

In summation, I would recommend:

- (1) that methods of recycling waste fluids be developed such that the ideal situation of little or no waste water may eventually be approached;
- (2) that the toxicity of all the chemicals used in all industries be evaluated in relation to their effect on the environment;
- (3) that alternative chemicals be developed which are less toxic than those currently used;
- (4) that methods of detoxifying effluents be evaluated such that each situation can be effectively and cheaply dealt with;
- (5) that samples of all effluents, whether they have been treated or otherwise, be finally checked for toxicity prior to disposal by using some species of live animal.
- (6) that Research and Development be encouraged by the surveillance arm of the Government such that there is an incentive gain to research. This could be managed via tax relief, but should result in improved practices (i.e. reduction in volume of waste water and/or development of more effective, less toxic chemicals).

Q. 14. Are there any threats to humans, wildlife or plant life if a gas well blows out?

A. Yes, there could be.

Q. 15. Would you outline some of these threats and indicate what precautions can be taken to minimize them?

As previously mentioned hydrogen sulphide and mercaptans are generally poisonous. Aside from this, pure hydrocarbons when mixed with air

can be inflammable or even explosive. Finally, fluids are sometimes produced with natural gas which are slightly soluble in any water contacting them (as mentioned earlier) and these solutions can be dangerous. Plants can also suffer from contact with components of natural gas such as ethane or hydrogen sulphide, as well as being adversely affected by contained materials such as salt. Fortunately the threat to human beings is relatively small unless unusual circumstances are encountered such as:

- (1) extremely sour gas may fill a depression or hollow where people are or have to go, either deliberately or inadvertently;
- (2) very high pressure gas may escape from a ruptured flow line in the presence of people. Gas at a high pressure can cut like a knife.

It is possible that the remote chance of injury could be alleviated by ensuring:

- (1) that people be constrained to stay away from high-pressure flow lines either by a wide-ranging educational programme, warning signs or other such devices applicable to the situation;
- (2) that production lines, flow lines and well heads generally be routed away from low basins such that the chance of pockets of poisonous or inflammable gas being liberated is much reduced;
- (3) that well-heads be protected by reinforcements commensurate in strength with the class of impact possible e.g. extremely strong where shifting ice is involved, probably less strong for other factors.

Q. 16. As a chemist, do you have concerns about possible adverse environmental effects of any other compounds, or groups of commercial chemicals, that can be used in the petroleum industry?

A. Many materials used in the petroleum or any other industry can be dangerous particularly if mis-used. Special phosphate ester high-temperature lubricants (often used to lubricate compressors or their power sources), metallic soaps used in greases, red-lead pipe dope,

additives used in gasoline, and other chemicals used in the drilling industry all are capable of creating problems.

Mixing detergents or dispersants with oils of any kind often produces synergistic results in toxicity. Fortunately sensible usage of these materials can be made as safe as the usage of fires for heating. Under control, wisely used, they can be great blessings to the user.

Q. 17. Why has sulphur dioxide received so much attention by scientists and regulatory agencies in Alberta?

Sulphur dioxide can be part of the air-carried dust generated by burning sulphur or hydrogen sulphide. If the air circulates in the open, the SO_2 can be so widely dispersed that it will create no immediate problem. Concentrations of SO_2 , even at a very low level, are very irritating and can cause damage to plants and animals quite quickly. If SO_2 must be generated and released it is common practice to ensure that it is expelled from a considerable height (from tall stacks) to ensure rapid and extensive dilution with the surrounding atmosphere.

Q. 18. Gas discovered to date in the Mackenzie Delta region is sweet gas. Aside from the possibility of sour gas being found in other gas fields in this area in the future, in your opinion is it possible for a sweet gas field to turn to sour gas as the reservoir is depleted?

I believe that this could occur since a bacterium (*Desulphovibrio desulphuricans*) is capable of living in oil reservoirs. It can strip the oxygen from the sulphate radicle and eventually generate hydrogen sulphide. *Desulphovibrio* sp. could enter a reservoir at the time a well was drilled, but probably the easier way for them to enter a reservoir is for them to be inadvertently pumped into the reservoir with the pressure maintenance water being pumped into the bottom of the reservoir in an attempt to improve the amount of oil eventually recovered from the reservoir.

One should bear in mind that this pressure maintenance is usually not practiced on gas pools.

Q. 19. Do you have knowledge of any adverse environmental effects resulting from sub-lethal concentrations of chemical compounds associated with the petroleum industry?

A. Unfortunately, there is very little in the literature on the sub-lethal effect of: chromium from the chromo ligno sulfonate thinners; or potassium from the potash muds; or from the lignins; or lignites; or the hundreds of other additives. One should probably assume that, in a sensitive environment, there could be adverse effects in the ecosystem, but much research is needed to determine what these potential effects are, how they might be minimized, and which are the worst offenders to specific plants and animals.

Q. 20. From your experience, are there ways that the "bentonitic clays" associated with drilling can be safely disposed of provided adequate steps are taken?

A. Yes.

Quite commonly the clay component of drilling fluids can be caused to flocculate and coagulate. The resultant "clobbered" mud (if fairly dilute) will settle, leaving a clear supernatant fluid on top. The fluid so treated could also be more readily centrifuged or filtered clear of its suspended solids. The clear fluid could be tested for its toxicity, and either detoxified if toxic, or disposed of directly if non-toxic.

Q. 21. Do we know what effect a surface coating of bentonitic clay might have upon lichens?

A. Only in a general sense of what I would expect, and that is that if light and air are shut off from a plant then it is probable that the plant will suffer. Specific effects would depend on the drilling mud and on the types of plants involved. I rather expect that a considerable amount of work needs to be done on this, but the professional botanists could better elucidate this need.

Q. 22. We often hear of burning as a clean-up technique for spilled oil. What happens to a soil surface when you burn off an oil spill?

A. That depends on the season of the year, the amount of oil and on how wet the ground is. If the area is dry and it is summertime any free oil should be collected and removed as soon as possible. Generally, the residues should not be burned since the act of burning tends to kill or disadvantage the plants that may be minimally effected by the oil itself. Burning also tends to reduce the number of bacteria in the soil by cooking them, and also tends to leave a waxy or asphaltic scum on the burn area. It appears then to be more difficult to get rehabilitation steps quickly started. When one has gained a lot of experience, I suspect that there are situations in winter where oil spills on thick unflawed ice might be advantageously burned to remove the residual oil.

Q. 23. Can you make any recommendations as to circumstances under which oil could be burned off and the circumstances under which burning would not be a desirable clean-up technique?

Generally, I would consider burning as an aid to clean-up in winter, but would be very cautious in summer. I would also want to know more about the effect of oil spills on thawed and frozen tundra before I was entirely sure of the probable effects. If the botanists feel that the tundra is exceptionally sensitive I would be very cautious about burning.

Q. 24. A March 1975 Forestry Report, published by the Northern Forest Research Centre in Edmonton showed an aerial photograph of the Swan Hills oil field. In this particular area there is a very dense network of surface disturbances. Is this intensity of surface disturbance inevitable after one or two decades of petroleum development?

A. Not necessarily. One should consider the Medicine Hat gas field where the wells are generally at least a mile apart. One should also consider whether the reservoir could be depleted satisfactorily from single locations from which many long-distance whip-stocked or directionally drilled holes emanated. However, this could be impractical, expensive, and dangerous. It might possibly be better to devise a pre-existent pattern of least roadways to cover the most territory with the least surface disturbance. Methods of road building, winter drilling programmes restricted to the arctic night, and other procedures if properly investigated might minimize the environmental impact; not only on the present but in future activity.

Q. 25. In your opinion, is surface disturbance from oil and gas field development a significant contributor to siltation of streams and lakes in central and northern Alberta?

It may be. I have heard that silt carried from the Swan Hills oil field via the Swan River has caused siltation in Lesser Slave Lake.

Q. 26. In Alberta, does condensate from gas lines ever escape into the environment and are there harmful environmental effects from the chemical makeup of this condensate?

Yes, condensate does sometimes get spilled from various accidents, and yes the hydrocarbons mercaptans, and sulphur can be harmful. Fortunately, these are rare occurrences in Alberta.

APPENDIX I

REPORTS REFERRED TO OR RELIED ON

- (1) Private communication from Dr. Beck, Department of Agriculture,-----
Veterinary Services Division, Edmonton.
- (2) Worker's Compensation Board, Bulletin SB - 02 - 74 entitled "The
killer - H_2S ".
- (3) Rogers, W. F. 1948. Composition and properties of oil well drilling
fluids. Gulf Publ. Co., Houston, Texas.
- (4) McCray, A. W. and Cole, F.W. 1958. Oil well drilling technology.
Univ. Oklahoma Press.

APPENDIX II

Biographic Information - D. R. Shaw

Present Position - Chief Chemist
Energy Resources Conservation Board
Chemical Laboratory, Engineering Building
University of Alberta
Edmonton, Alberta T6G 2G7

Mr. Shaw began working in the Turner Valley oil and gas field in early 1942 as a labourer at the British American Oil Co. gas plant at Longview. There he held a variety of jobs: store-man; field-guager; instrument mechanic and other positions. After service overseas with the Canadian Army Active Forces he returned to British American as a high pressure compressor operator.

He then attended the University of Alberta and obtained a B.Sc. in Honors Chemistry in 1950. During this period, he worked in summers for Consolidated Mining and Smelting, as a "mud-man" for Commonwealth Drilling, and also as a "roughneck" for Commonwealth Drilling. After 1950 he went to the University of British Columbia and did some work towards a Masters' degree. He left U.B.C. to work in the pulp and paper industry as a pulp tester and as a chemist.

In 1953 Mr. Shaw returned to Alberta and worked as a "mud-man" for various companies. In 1955 he began working for the Energy Resources Conservation Board and has been with the Board ever since. During the past two years, Mr. Shaw began a study programme that would have led to an M.Sc. in zoology at the University of Alberta. However, the exigencies of his present employment did not leave sufficient time to complete the study programme so he withdrew as a candidate.

Mr. Shaw is presenting this evidence to the Mackenzie Valley Pipeline Inquiry as a private citizen and not as an official representing or necessarily expressing the views of the Energy Resources Conservation Board of Alberta.

